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Multilateral versus bilateral testing for long run Purchasing Power Parity: A cointegration analysis for the Greek drachma.

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Abstract

Problems faced by empirical studies of the purchasing power parity (PPP) hypothesis are: the choice between a multilateral and a bilateral approach, the choice of the appropriate price index and the problem of simultaneous determination of prices and exchange rates. In the present paper, we analyse the implications that these problems have, while testing for the PPP doctrine between Greece and its three major trading partners during the recent floating exchange rate period. Long-run PPP is tested as an exchange rate-price cointegrating relationship by applying a multivariate maximum likelihood procedure, using two alternative price measures.

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1 Introduction

Purchasing power parity (PPP) states that the exchange rate between two currencies is determined by the change in the two countries' relative prices. The notion underlying this is that deviations from the parity represent profitable commodity arbitrage opportunities which, if exploited, will tend to force the exchange rate towards the parity. Since the return to a floating exchange rate regime in the early 70's, PPP has been used as at least a long run relationship in most of the international economic models as much as it has been the focal point of exchange rate policy (see *inter alia* Dornbusch (1988), MacDonald and Taylor (1992)). As a consequence, its empirical verification as either a short run or a long run relationship has been the purpose of a large number of applied papers, with cointegration analysis (introduced by Engle and Granger (1987)), used in the most recent ones as an important tool to test for its existence in the long run. In general, the empirical evidence in favour of the PPP condition has been rather weak (see Dornbush (1989)). In addition, most of the empirical works of the PPP hypothesis present a few common problems which are essentially the choice between a multilateral and a bilateral approach, the choice of the price index and the problem of the simultaneous determination of prices and exchange rates.

The two most recent studies which analyse PPP using Greek data during the recent floating exchange rate period are Karfakis and Moschos (1989) and Dockery and Georgellis (1994)[1]. In both papers the authors use the Engle and Granger (1987) two step technique and adopt the bilateral approach for testing for PPP. Karfakis and Moschos (1989) use quarterly unadjusted series for the exchange rates and two alternative price measures of Greece and its six major trading partners for the period 1975(1)-1987(1); they find no evidence of long run PPP. Dockery and Georgellis use monthly unadjusted series for nine European trade partners of Greece for the post EEC period 1980(4)-1992(8); they use consumer prices and again they find

[1]While Georgoutsos and Kouretas (1992) test for long run PPP between Greece and main economies for the floating exchange rate regime period of the 20's.

no evidence of long run PPP in most cases[2].

The present paper extends the existing literature on long run PPP for the Greek drachma by giving particular emphasis to the methodological problems presented in the literature. Long run PPP between Greece and its three major trading partners is tested as a cointegrated equilibrium relationship, by making use of two alternative price measures, the consumer price index p^c and the wholesale price index p^w. The analysis is initially made in a multilateral framework in an effort to capture the bilateral bias (the fact that the bilateral analysis does not take into account the correlation between exchange rate movements). In a second step, the strength of the bilateral specifications is evaluated by formal testing against the general multicountry models. Finally, PPP is tested in bilateral systems and the results obtained are compared with the multilateral ones.

Both multilateral and bilateral analyses are performed in a multivariate framework which is consistent with the "general to specific" tradition. Initially vector autoregressive (VAR) models in levels are considered, which describe the statistical properties of the data. Then, the Johansen (1988), Johansen and Juselius (1990) cointegration technique is applied, which leads to the determination of the number of the cointegrating long run relationships and allows testing for the hypotheses of interest expressed as linear restrictions on the cointegrating parameters[3]. The basic advantage of the methodology compared in particular with the Engle and Granger's (1987) residual based technique used in the aboved mentioned studies of the Greek experience, is that it allows for possible interactions in the determination of the variables and no variable has to be considered *a priori* exogenous. In addition, the model specification used for cointegration allows for different long run relations and short run dynamics and for adjustment for specific regime shifts which may have occurred during the examined period; this is important since such shifts can distort statistical

[2]In particular, they find no evidence for PPP for the countries Germany, France, Italy, Belgium, Holland and Denmark, while they find PPP evidence for the countries UK, Spain and Portugal.

[3]Testing for PPP for main exchange rates using the Johansen methodology has provided new results (see *inter alia* Johansen and Juselius(1992), Hunter (1992), Cheung and Lai (1993a), Juselius (1994), Chen (1995), McDonald and Marsh (1995)).

tests that do not account for them. Finally, it allows for more than one cointegrating vector.

The rest of the paper is organised as follows: Section 2 describes briefly the theory underlying the PPP doctrine and outlines the problems related to the empirical PPP literature. Section 3 gives an overview of the econometric methodology applied, while in Section 4 the data set is presented. Sections 5 and 6 analyse the applied work done in a multilateral and a bilateral framework respectively, and interpret the results. The final section summarises and concludes.

2 The existing literature.

2.1 The economic background

PPP states a theory of exchange rate determination. Letting p, p_f indicate the logs of the price levels of the domestic and the foreign economy respectively, and e be the log of the exchange rate denominated in the currency of the domestic economy, the **"strong" PPP** version states that:

$$e = p - p_f \tag{1}$$

implying that, whatever the monetary or real disturbances in an economy, under the assumption of instantaneous costless arbitrage, the prices of a common basket of goods in the two countries measured in a common currency will be the same.

However, even though there cannot be any objection to (1) as a theoretical statement, it cannot be expected to hold always as an empirical proposition. The prices of a given commodity will not necessarily be equal in different locations, because of transportation costs, possible tariff barriers and information costs. Moreover, measurement error problems, arising from published price indices not coinciding with the theoretical prices, should also be taken into account when PPP is tested empirically[4].

[4] An implicit assumption for PPP to hold when tested using aggregate price indices is

Therefore, the relationship is more likely to take the following **"weak" PPP** form:

$$e = \gamma(p - p_f) \tag{2}$$

with γ being a constant factor which accounts for assumed constant transportation, information costs and measurement errors. In (2), γ is allowed to differ from unity, implying that long run proportionality between the exchange rate and relative prices may not be exactly one-to-one (see Taylor (1988), for the derivation of (2) in a model allowing for transportation costs and measurement errors).

However, even in its weak form (2), PPP does not necessarily hold in the long run, given that changes in tastes cause shifts in exports demand, the different relevant importance of the tradeable to the nontradeable sectors, as well as the difference in more fundamental factors such as productivity, government spending and stategic pricing decisions by firms would cause exchange rate movements beyond the PPP level (see Froot and Rogoff (1995) for a survey of the structural models that explain deviations from PPP).

Finally, exchange rates are also determined through transactions in the asset markets, related to the interest rate differentials between different countries. (For that reason, Johansen and Juselius (1992a), McDonald and Marsh (1995) suggest testing for PPP in a framework which includes interest rates, in an attempt to capture any special financial market effects). Therefore, temporary departures from PPP can be explained by asset markets clearing faster than commodity markets, thus leading to exchange rates being temporarily influenced by "news" effects.

2.2 Empirical problems.

The main problems of the empirical PPP literature (see *inter alia* Giovannetti (1992)) are:

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that each good is equally weighted in the indices of the different economies. International differences in consumption patterns, variations in product qualities and differences between listed and transaction prices are some of the reasons for different weighting of the price indices.

1. A bilateral versus a multilateral approach: Bilateral testing for PPP has often been criticised for ignoring the correlation between exchange rate movements. Dealing with this problem by using trade weighted series has also been criticised for being arbitrary in terms of the choice of weights. In addition, it has the drawback that it implies that the relative importance of different countries' prices in determining domestic prices changes if and only if, the trade pattern changes.

In the present application, a multi-country analysis in systems which account for the interractions of exchange rates and prices between more than two countries simultaneously is first attempted. Then, (in line with the "general to specific" methodology) reduced two-country systems are formally tested against the more general ones in terms of the robustness of the cointegration results. Finally, a bilateral analysis is performed in an attempt to test whether the results obtained confirm the multilateral analysis results.

2. The choice of the price index: Empirical studies considering PPP as an arbitrage relationship advocate the use of traded goods indices such as export prices or the wholesale price index. Studies taking into account the different pricing behaviour in goods and asset markets on the other hand, support the use of more general price measures such as the consumer price index, or the GDP deflator. In the present work, both approaches are followed, by using both consumer and wholesale price indices and the results are interpreted accordingly.

From a theoretical point of view, the p^w is the adequate price measure to be used in the present work, given that the Greek asset market was relatively closed during the period under study. However, examination of the way in which the indices are computed reveals differences between the methodologies used to compile the p^ws in Greece and in the other countries, while this is not so for the p^cs. Similar household expenditure measures, rent and product prices are included for the p^c compilation for all countries under study (see OECD (1994) supplement); the p^c indices also cover similar geographical area and population (see IFS (1986) supplement, p. 217-219). On the contrary, the methodologies in which the p^w s are compiled differ from country to country: The various p^ws include different groups of industry commodities weighted in a quite judgmental way by the compilers of the national statistical institutions. The Greek w^p for example, includes exported domestic goods, while this is not so for the indices of the rest of the countries. As a consequence, the p^c index is a better comparable measure to test for PPP than the p^w, in terms of measurement precision.

3. Endogeneity/ exogeneity status of the variables: The question is whether the price or the exchange rate series is the endogenous variable in the PPP relationship. The arbitrage based theory advocates exogenous prices (so it could be expected that this would hold in traded goods prices systems), while exogeneity for the exchange rates could only be supported by models taking into account the assets - goods markets forces interactions (therefore, more likely to be found in general price measure models). Contrary to most of the previous PPP empirical studies, including most of those using the Engle and Granger technique, application of the Johansen maximum likelihood technique allows the endogeneity/ exogeneity status to be evaluated statistically, rather than imposed *a priori*.

3 The econometric Methodology

The analysis follows the "general to specific" methodology[5]. The basic elements of this methodology are that the stochastic properties of the series of interest have to be accounted for, the measurement system (e.g. degree of aggregation) might influence the model specification, and that theoretical and observed variables may be two distinct concepts. In a systems context, the initial step suggested by the methodology is the approximation of the joint distribution of an $N \times 1$ vector of the time series of interest $\mathbf{x}_t$, (perhaps after transformation to ensure that linearity is reasonable) by a vector autoregressive representation (VAR) of the form:

[5]For a detailed analysis of the methodology, see *inter alia*, Hendry (1995), Spanos (1986).

$$A(L)x_t = \mu + \psi D_t + \nu_t \tag{3}$$

where $\nu_t \sim IN(0, \Sigma)$, μ is a constant and D_t contains conditioning variables such as seasonals, event dummy variables and relevant exogenous variables which influence only the short run behaviour of the process. In model (3):

$A(L) = \sum_{j=o}^{k} A_j L^j = I_N + A^*(L)L$,

which is a k^{th} order matrix polynomial in the lag operator L with A_0=I_N. Also, $\{A_j\}$ and Σ are unrestricted; the initial values x_{1-k}, x_{2-k},..., x_0 are fixed and k is finite, so that moving average components are excluded. These assumptions, together with those about independence, normality and homoscedasticity, are not fundamental, while the assumption about constant parameters of interest $\{\mu, A_1, ..., A_k, \psi, \Sigma\}$ is.

As long as a VAR of the form (3) is shown to be a congruent representation of the available information for the variables of interest, (thus not rejecting the statistical assumptions underlying it), it can be used to test for the existence of cointegrating relationships among the series. In the case that they exist, the cointegrating relationships can then be used in the modelling, given that standard statistical inference can be made. In addition, they can be given the interpretation of equilibrium long run relationships among the included variables. Model (3) can be reparameterised in an error correction form as:

$$\Delta x_t = -\sum_{i=1}^{k-1} \Pi_i \Delta x_{t-i} + \Pi x_{t-k} + \mu + \psi D_t + \nu \tag{4}$$

where $\Pi_i = -(I_N + \Sigma_{j=1}^{i} A_j)$ and $\Pi = -(I_N + \Sigma_{j=1}^{k} A_j) = -A(1)$ and Π is the matrix of the long-run responses. Then, and in the case that the series are at most integrated of order one I(1), the maximum likelihood technique suggested by Johansen(1988), Johansen and Juselius (1990) can be used to test for the rank of the matrix Π, by computing two likelihood ratio test statistics, the "trace statistic" and the "maximal eigenvalue statistic".

If there exist r cointegrating relationships between the variables, Π is of reduced rank $r <$N. In this case, Π can be expressed as the product of two N×r matrices α and β', where β contains the r cointegrating vectors and α is the loadings or adjustment parameters matrix, which contains the loadings with which the cointegrating relationships enter the equations modelling $\Delta \mathrm{x}_t$.

The hypothesis of cointegration is given by:

$$H_{01} : \Pi = \alpha\beta' \tag{5}$$

Further, linear restrictions on either the parameters of the cointegrating vectors β_i or their loadings α_i can be tested (which form hyptheses against H_{01}). The importance of testing restictions on α_i and β_i in part stems from the fact that the matrices α and β' are not unique: any linear transformation of, say, β' by a nonsingular r×r matrix Θ, leaves Π unchanged:

$$\Theta\beta' = \beta^* \rightarrow -\alpha\Theta^{-1}\Theta\beta' = \Pi \tag{6}$$

In this framework, restrictions on β which imply theoretical hypotheses for the long run behaviour of the series can be expressed as:

$$H_{02} : \beta = \Xi\phi, \tag{7}$$

Certain zero restrictions on α can be expressed as:

$$H_{03} : \alpha = A\psi \tag{8}$$

Zero restrictions on α are of importance given that they test whether or not the cointegrating vectors enter the equations modelling the determination of the series. Therefore, certain zero restrictions on α are required for the weak exogeneity of the variables for the long run parameters[6], while others suggest that a reduction of the initial system is robust in terms of the cointegration results. Finally, joint restrictions on β and α can also be formed as:

$$H_{04} : (\alpha = A\psi), (\beta = \Xi\phi) \tag{9}$$

[6] For a detailed analysis on exogeneity testing see *inter alia* Ericsson (1992).

In (7), (8) and (9) the matrices $\Xi_{N\times s}$ and $A_{N\times m}$ define known linear restrictions, while $\phi_{s\times r}$ and $\psi_{m\times r}$ incorporate the restrictions on the individual values of the cointegrating space. Hypotheses of the forms (7), (8) and (9) can be assessed by a likelihood ratio test statistic of the form:

$$T\sum_{i=1}^{r} log\{(1-\lambda_i^*)/(1-\lambda_i)\} \tag{10}$$

where λ_i^*, λ_i are the r largest eigenvalues of the restricted and the unrestricted model, respectively. The statistic is asymptotically distributed as a χ^2 with $r(N-s)$ degrees of freedom when testing for H_{02}, $r(N-m)$ when testing for H_{03}, and $r(N-s)+r(N-m)$ when testing for H_{04}.

4 The data set.

PPP is tested for Greece and its three major trading partners for the period examined: Germany (G), France (FR) and Italy (IT). As shown in Table 4.1, more than one third of Greece's trade is with these three countries. Almost two thirds of the Greek imports are received from European countries, more than half of them from the EU members. Germany is the most important trading partner, accounting for approximately 18% of Greek total imports and 20% of Greek total exports, followed by Italy (11% of imports, 10% of exports) and France (7% of imports, 6.5% of exports)[7].

Quarterly seasonally unadjusted data for the post Bretton-Woods period 1975(1) to 1993(4) are used. The price series are IMF series; they were all obtained using the DATASTREAM data bank. The drachma exchange rate and the Greek trade series were taken from the *Greek Monthly Statistical Bulletin* of the *Bank of Greece*, various issues. The sample is shorter in a number of cases due to non availability of data[8], and effective

[7]Those countries are followed by the US (6% of imports, 7% of exports) and the UK (5% of imports, 6% of exports), but extension of the analysis to test for PPP between Greece and the UK and the US is not attempted in the present work. It is done, though, in a bilateral framework in Sideris (1994).

[8]For France, the wholesale price index is not available before 1980(2), and the Greek drachma/Italian lira exchange rate series is not available before 1978(1).

estimation periods are reduced so as to accomodate the lag structure of the estimated models.

Table 1: **Trade with major trading partners (1975 - 1993)**[1].

Country	Imports (%)	Exports (%)
Germany	18	20
Italy	11	10
France	7	6.5
All three countries	36	36.5
EEC countries	52	48
EEC & OECD Europe	66	59

[1]The percentages are calculated using averages for the period 1975(1)-1993(4). Data are taken from the *Greek Monthly Statistical Bulletin* of the *Bank of Greece* , various issues.

The variables used are the logs of the exchange rates of the drachma against the Deutsch mark e_G , the Italian lira e_{IT} and the French franc e_{FR} and two alternative price measures, the consumer price index and the wholesale price index in Greece p^c_{GR} and p^w_{GR} respectively, and in the six countries p^c_f, p^w_f, where f denotes foreign country and takes the values G, IT, and FR for the countries Germany, Italy and France, respectively. The graphs of the series are presented in Figure 4.1.

5 Testing for PPP in a multilateral framework.

5.1 Specification of the VAR models.

In this first stage, the bilateral bias in PPP testing is dealt with by the specification of multicountry systems which model the price and exchange rate interractions among more than two countries simultaneously. In addition, in multilateral models the domestic prices are regressed against the prices of the domestic country's major trade partners, allowing the relative importance of the different countries prices in determining domestic prices to be directly determined from the data.

The initial aim was to test for PPP simultaneously between Greece and its three major competitors Germany, Italy and France, in four-country systems (seven-dimensional VARs) using the two alternative price index specifications. However, given the available sample period, analysis of seven dimensional VARs would mean loss of valuable degrees of freedom. It was therefore decided to do the analysis in five-dimensional VARs allowing for possible interrelations between Greece and two of its major partners at a time.

Four three-country VAR systems are estimated: (A) and (B) model simultaneously the price- exchange rates interrelations between Greece and: (a) Germany and France, and (b) Germany and Italy repectively, using p^c's; (C) and (D) model the price- exchange rate movements between Greece and: (c) Germany and France, and (d) Germany and Italy, using p^w's. Estimation is done by application of the multivariate least squares technique using five lags for the variables, with a constant and centred seasonals included in the deterministic variables set D_t[9].

Likelihood ratio tests (provided there were non autocorrelated residuals in the reduced systems) indicated the number of lags to be four in system (D) and five in the rest of the systems. All initial VARs rejected the null of normal residuals, possibly due to non-constant parameters as indicated by the plots of one-step Chow tests against the end point of the samples (not shown to save space). These features supported the inclusion of impulse dummy variables to account for the regime shifts/ structural breaks observed in the examined period, which (as advocated by Clements and Mizon (1991)) is preferable to an enlargement of the system.

In fact, two severe regime shifts in the form of two drachma devaluations took place during this period: the first one in January 1983, and the second one in October 1985. The second initially caused sharp rises in

[9]All results reported in the paper are obtained using the PC-GIVE and PC-FIML modules of the PC-GIVE.8 system of computer programs (see Doornik and Hendry (1994)).

Greek prices, with inflation reaching its highest point in the first quarter of 1986. The shift dummies D831 and D854 accounting for the first and second devaluations turned out to be significant in all systems, while their absence would have meant non normal residuals for the exchange rate and Greek price equations of them[10]. The dummy D924 which accounts for the withdrawal of major European currencies (including the Italian lira) from the ERM in September 1992, also had to be included in the Greek-German-Italian systems. Finally, a number of other specific dummies related to the performance of Greece's trading partners were included in the relevant VARs; a description of the structural breaks which they account for is given in Appendix 1.

Tables 1 and 2 in Appendix 2 summarise the properties of the preferred VARs residuals. The number of lags of the endogenous variables used and the variables contained in the D_t set for each VAR are given in the first lines of the tables.

First, single equation diagnostics are reported: The AR Lagrange multiplier (LM) statistic for residual serial independence across the mentioned lags of the autocorrelation function and the N statistic testing the null of normal skewness and kurtosis. Second, test statistics for vector autoregressive residuals $VecAR$ and vector normality $VecN$ which make use of auxiliary systems to assess serial correlation and non normality in the VAR as a whole are reported (for definition of the tests, see Doornik and Hendry (1994)). The diagnostics do not indicate serious autocorrelation and non-normality problems for the VARs residuals. In a couple of equations, the hypothesis of either non autocorrelation or nonnormality of the residuals was marginally rejected. In addition, (with respect to the non normality evidence) since the Johansen technique has been demonstrated to be robust to nonnormality by Cheung and Lai (1993b) and Gonzalo (1994), it was decided to continue the analysis without altering the VAR specification.

[10]While the shift dummies D832 and D861 which account also for the same effects turned out to be significant in a number of cases.

5.2 Cointegration Analysis.

5.2.1 The Long-Run structure of the VAR system A.

The cointegration space rank.

Model (3) as specified in section 3 for a vector of the form: $x_t = (e_{FR}; e_G, p^c_G, p^c_{GR}; p^c_{FR})$ with the required assumptions fulfilled as described previously provides the framework to perform the multivariate cointegration analysis. Inspection of the graphs of the series shown in figure 1, indicate that the series have an approximate linear trend: therefore, model (3) is estimated without imposing the linear restriction of the constant to be included only in the cointegrating space. The outcomes of the maximum eigenvalue and trace statistics, the estimated eigenvectors and their loadings are reported in Table 5.1. Both likelihood ratio tests support the cointegrating space rank to be three, so we continue the analysis based on this assumption.

Finally, the robustness of the three cointegrating vectors is assessed by visual examination of the graphs of the recursive estimates of the eigenvalues, given that they can be used as a valuable check for parameter constancy (see Mizon (1995)). Their graphs given in figure 2 indicate parameter constancy of the cointegrating relations.

Identification of the Long Run structure.

The three estimated unrestricted cointegrating vectors seem to imply theoretically interpretable relations. In the first one, the exchange rates e_G and e_{FR} have coefficients which are almost equal in size, and have opposite signs: the two variables together could be given the interpretation of the Deutsch mark/French frank exchange rate; in addition, the p^c_{GR} coefficient is quite small in size, while the signs of the coefficients of the variables p^c_G and p^c_{FR} are the ones that could support a PPP relation between Germany and France. The second cointegrating vector could imply a PPP relation between Greece and Germany with coefficients quite close to unity. Finally, the third vector cannot be given a theoretical interpretation at the present

Table 2: **Cointegration analysis of system (A).**

Testing for the Π rank.

Eigenvalues	H_0	Max. Eigen.	95%	Trace	95%
0.660	r = 0	76.75**	33.5	146.8**	68.5
0.360	r $\leq$ 1	31.74*	27.1	70.07**	47.2
0.261	r $\leq$ 2	21.49*	21.0	38.33**	29.7
0.195	r $\leq$ 3	14.05	14.1	15.31	15.4
0.003	r $\leq$ 4	0.267	3.8	0.267	3.8

Standardised eigenvectors.

e_{FR}	e_G	p^c_G	p^c_{GR}	p^c_{FR}
1	-0.924	0.064	-0.131	0.553
-0.478	1	1.438	-0.731	-0.283
-1.052	0.219	1	1.664	-3.211
-1.094	-0.697	2.405	1	-1.256
-2.380	-1.021	-13.63	4.036	1

Adjustment coefficients.

e_{FR}	-0.458	0.077	0.034	0.028	0.001
e_G	-0.064	0.041	0.009	0.066	0.001
p^c_G	-0.000	-0.007	0.014	-0.004	0.000
p^c_{GR}	-0.051	-0.022	-0.012	-0.011	0.004
p^c_{FR}	0.035	0.067	0.005	-0.002	0.005

stage, even though the signs of the e_{FR}, p^c_{FR}, p^c_{GR} variables could support a PPP link between Greece and France. Nevertheless, formal testing for possible theoretical assumptions is needed.

Table 5.2 presents the outcomes of a number of likelihood ratio statistics testing for alternative theoretical hypotheses concerning the specification of the three dimensional cointegrating space.

Hypotheses on a single cointegrating vector framework are initially considered. H_{A1} assumes a "weak" PPP relation between Greece and Germany for the specification of the second vector: it is accepted by the given data set. H_{A2} assumes "weak" PPP between Greece and France for the specification of the third vector: it is marginally rejected by the data. H_{A3} which expresses a cointegrating long run relation between the Deutsch mark/ French frank exchange rate and the German and French prices for the first vector does not form a constraint. "Strong" PPP between Germany and Greece implied by H_{A4} is accepted for the specification of the second vector. H_{A5} testing for "strong" PPP between Greece and France for the specification of the third vector is accepted. Finally, H_{A6}, which tests for "weak" PPP between Germany and France, even though accepted by the data set, does not provide a relation with the theoretically expected signs for the coefficients.

H_{A7} tests jointly for H_{A1}, H_{A2} and H_{A3}: it is accepted by the given data sample.

H_{A8} tests jointly for H_{A4}, H_{A2} and H_{A3}: it is accepted.

H_{A9} tests jointly for H_{A4}, H_{A2} and H_{A6}: it is strongly rejected by the data.

H_{A10} tests jointly for H_{A4}, H_{A5} and H_{A3}: even though it is accepted, it does not provide a theoretically reasonable relation for the specification of the first vector, as the obtained signs of the coefficients are not the expected ones.

H_{A11} tests jointly for H_{A4}, H_{A5} and H_{A6}: it is marginally rejected by the data.

As a consequence, the analysis was continued by assuming that the structure of the cointegrating space can be trustfully given by the speci-

Table 3: **Testing system (A) for structural and exogeneity restrictions.**

Testing restrictions on single vector specification.

		e_{FR}	e_G	p^c_G	p^c_{GR}	p^c_{FR}	$\chi^2(dof)$	p-value
H_{A1}:	β_{A2}:	0	1	a	-a	0	3.414 (1)	0.064
H_{A2}:	β_{A3}:	1	0	0	-b	b	5.354 (1)*	0.020
H_{A3}:	β_{A1}:	1	-1		0		n a c	
H_{A4}:	β_{A2}:	0	1	1	-1	0	4.584 (2)	0.101
H_{A5}:	β_{A3}:	1	0	1	-1	0	4.652 (2)	0.097
H_{A6}:	β_{A1}:	1	-1	-c	0	c	3.364 (1)	0.066

Testing for joint restrictions.

		$\chi^2(dof)$	p-value
H_{A7}:	$H_{A1} \cap H_{A2} \cap H_{A3}$:	5.956 (2)	0.050
H_{A8}:	$H_{A4} \cap H_{A2} \cap H_{A3}$:	6.713 (3)	0.081
H_{A9}:	$H_{A4} \cap H_{A2} \cap H_{A6}$:	13.21 (4)**	0.010
H_{A10}:	$H_{A4} \cap H_{A5} \cap H_{A3}$:	7.942 (5)	0.159
H_{A11}:	$H_{A4} \cap H_{A5} \cap H_{A6}$:	14.77 (6)*	0.022

Testing for weak exogeneity restrictions.

		$\chi^2(dof)$	p-value
H_{A12}:	$H_{A8} \cap$ w. exog. of p^c_{GR} wrt β_{A2}:	9.532 (4)*	0.049
H_{A13}:	$H_{A8} \cap$ w. exog. of p^c_G wrt β_{A2}:	7.170 (4)	0.127
H_{A14}:	$H_{A8} \cap$ w. exog. of e_G wrt β_{A2}:	9.571 (4)*	0.048
H_{A15}:	$H_{A8} \cap$ w. exog. of p^c_{GR} wrt β_{A3}:	9.981 (4)*	0.040
H_{A16}:	$H_{A8} \cap$ w. exog. of p^c_{FR} wrt β_{A3}:	7.456 (4)	0.113
H_{A17}:	$H_{A8} \cap$ w. exog. of e_{FR} wrt β_{A3}:	7.098 (4)	0.130

Testing for reduction to bi-lateral systems.

H_{A18}:	$H_{A8} \cap$ w. ex. of p^c_{FR}, e_{FR} wrt β_{A2}:	21.91 (5)**	0.000
H_{A19}:	$H_{A8} \cap$ w. ex. of p^c_G, e_G wrt β_{A3}:	10.326 (5)	0.066
H_{A20}:	$H_{A8} \cap$ w. ex. of p^c_G wrt coint. space:	7.685 (6)	0.248

fication implied by H_{A8}. The three cointegrating vectors are of the form (standard errors in parenthesis):

$$\beta_{A1} : (e_{FR} - e_G) + 0.787(0.033)p^c_{FR} - 0.852(0.080)p^c_G$$

$$\beta_{A2} : e_G + p^c_G - p^c_{GR}$$

$$\beta_{A3} : e_{FR} - 0.962(0.017)(p^c_{GR} - p^c_{FR})$$

β_{A2} expresses a "strong" PPP relation between Greece and Germany, while β_{A3} a "weak" PPP relation between Greece and France, with coefficients very close to unity. Finally, the first vector β_{A1} expresses a relation between the Deutsch mark/ French franc exchange rate and the French and German price indices, which is very close to a "weak" PPP relation between the two countries.

Weak exogeneity tests.

As shown in Johansen (1992), a necessary condition for Δx_{it} for some i, to be weakly exogenous for α and β is that $\alpha_i = 0$. In that case, Δx_{it} is weakly exogenous for α and β in the sense that the conditional distribution of Δx_t given Δx_{it} as well as the lagged values of x_t contains the parameters α and β, whereas the distribution of Δx_{it} given the lagged x_{it} does not contain the parameters α and β.

Weak exogeneity tests are reported in the lower part of table 5.2. H_{A12}, H_{A13} and H_{A14} test for weak exogeneity of p^c_{GR}, p^c_G and e_G respectively, with respect to the parameters of the long run Greek-German strong PPP: weak exogeneity is rejected for e_G and p^c_{GR}. The results imply that while p_G's are determined independently of the long run relationship that characterises the determination of the mark/drachma exchange rate, e_G and p_{GR} do not. H_{A15}, H_{A16} and H_{A17} test for weak exogeneity of p^c_{GR}, p^c_{FR} and e_{FR} respectively, with respect to the vector expressing the "weak" French-Greek PPP relationship: weak exogeneity of p^c_{GR} is only rejected.

Testing for reduction to bilateral systems.

Finally, a number of joint weak exogeneity assumptions that can be considered as necessary conditions for reduction to bi-lateral systems' cointegration analysis are performed. H_{A19} tests whether the German variables are weakly exogenous with respect to the Greek-French PPP relationship and is accepted by the data set. However, H_{A18} which tests whether the French variables are weakly exogenous with respect to the Greek-German PPP relationship is not accepted by the data set.

The results suggest that determination of the e_{FR} is highly influenced by the long run movement of the e_G rate. From a statistical point of view, they imply that while reduction to a bi-lateral German-Greek system is allowed, the cointegrating relationship of the variables p^c_{GR}, p^c_{FR} and e_{FR} necessitates modelling of the joint distribution of the complete system of the five variables. Finally H_{A20} which tests for weak exogeneity of the German prices for the whole cointegration space is accepted by the given data set.

The data support PPP relationships between Greece and Germany and Greece and France. Between the two relationships, though, the Greek-German PPP seems to be the most robust one (implying that p^c_{GR} and e_G move in a way to keep constant the competitiveness between the two countries). The Greek-French PPP seems to be a "secondary" relationship explained probably by the EMS performance of the French currency (the fact that the French franc was linked to the mark for most of the period examined): e_{FR} turns out to be weakly exogenous with respect to the Greek-French PPP but not with respect to the Greek-German PPP parameters of interest; in addition, the Greek-French PPP is shown to be obtained only by analysis of the joint distribution of the series.

5.2.2 The Long-Run structure of the VAR system B.

Determination of the cointegration space rank.

Application of the multivarate cointegration technique on the Greek-German-Italian system as specified in the previous subsection (5.1) gave us the results presented in Table 4.16. The estimation was done again without imposing the restriction of the constant to lie in the cointegrating space, given that the series have a linear trend. Both likelihood ratio tests give evidence of two cointegrating relations. The two recursively estimated eigenvalues shown in figure 3 are constant. Interpretation of the two long run relations is again not straightforward.

Identification of the long-run structure.

A number of theoretical hypotheses concerning the specification of the cointegrating space were tested formally. The outcomes of the likelihood ratio tests are given in the upper part of Table 5.4.

First, hypotheses on a single vector framework were tested. Hypothesis H_{B1} tests for "weak" PPP between Greece and Germany and it is accepted by the given data set. Hypothesis H_{B2} tests for unity coefficient for the drachma/lira rate and equal and opposite coefficients for the Greek and Italian prices, restrictions which could imply weak PPP between the two countries. Even though it is accepted by the given data set, the relation obtained is of the form $e_{IT} = 19.61(p^c_{GR}/p^c_{IT})$ which does not express a "weak" PPP relation. H_{B3} tests for cointegration between the lira/mark rate and the German and Italian price indices (if accepted, it would motivate further investigation for "weak" PPP between Germany and Italy): it is strongly rejected by the data. H_{B4}, which tests for PPP between Greece and a weighted average of the German and Italian price indices expressed in drachma terms, is also rejected by the given set. H_{B5} tests for cointegration between the price indices of the three countries and is accepted by the data. Finally, both H_{B6} and H_{B7}, which test for strong PPP between Greece and Germany, and Greece and Italy respectively, are strongly rejected.

Table 4: **Cointegration analysis of system (B).**

Testing for the Π rank.					
Eigenvalues	H_0	Max. Eigen.	95%	Trace	95%
0.673	r = 0	68.28**	33.5	124.6**	68.5
0.404	$r \leq 1$	31.62*	27.1	56.27**	47.2
0.216	$r \leq 2$	14.87	21.0	24.85	29.7
0.147	$r \leq 3$	9.703	14.1	9.783	15.4
0.001	$r \leq 4$	0.080	3.8	0.080	3.8

Standardised eigenvectors.				
e_{IT}	p^c_{GR}	e_G	p^c_G	p^c_{IT}
1	-4.946	2.400	7.106	2.171
-1.350	1	0.315	-1.771	-0.622
-3.509	2.856	1	-0.579	-2.776
0.464	-0.256	-0.280	1	0.054
1.016	0.175	-1.156	-1.824	1

Adjustment coefficients.					
e_{IT}	0.033	0.181	0.055	0.278	-0.0112
p^c_{GR}	-0.019	-0.017	-0.022	-0.259	-0.0114
e_G	0.022	0.210	0.034	0.413	-0.0134
p^c_G	-0.022	-0.005	0.001	-0.030	-0.0001
p^c_{IT}	-0.009	0.076	-0.010	-0.012	0.0004

Secondly, a few hypotheses concerning the structure of the two-dimensional cointegrating space were tested. H_{B8} tests jointly for H_{B1} and H_{B2}; H_{B9} tests jointly for H_{B1} and H_{B3}; H_{B10} tests jointly for H_{B1} and H_{B4}; H_{B11} tests jointly for H_{B1} and H_{B5}; finally, H_{B12} tests jointly for H_{B2} and H_{B5}; all but H_{B11} were strongly rejected by the given data set. As a concequence, it was decided to continue the analysis assuming that H_{B11} characterises the given data set. The two cointegrating vectors take the form (standard errors in parentheses):

$$\beta_{B1} : e_G - 0.752(0.091)(p^c_{GR} - p^c_G)$$

Table 5: **Testing system (B) for structural and exogeneity restrictions.**

Testing restrictions on single vectors specification.

		e_{IT}	p_G	e_G	p_{GR}	p_{IT}	$\chi^2(dof)$	p-value
H_{B1}:	β_{B1}:	0	a	1	-a	0	5.948 (2)	0.051
H_{B2}:	β_{B1}:	1	0	0	-b	b	3.903 (2)	0.142
H_{B3}:	β_{B2}:	1		-1	0		12.21 (1)**	0.000
H_{B4}:	β_{B2}:	c	d	d	1	c	4.820 (1)*	0.028
H_{B5}:	β_{B2}:	0	1	0	a	b	3.952 (1)	0.052
H_{B6}:	β_{B2}:	0	1	1	-1	0	18.66 (3)**	0.000
H_{B7}:	β_{B1}:	1	0	0	-1	1	18.12 (3)**	0.000

Testing for joint restrictions.

		$\chi^2(dof)$	p-value
H_{B8}:	$H_{B1} \cap H_{B2}$:	14.91 (3)**	0.001
H_{B9}:	$H_{B1} \cap H_{B3}$:	14.24 (3)**	0.002
H_{B10}:	$H_{B1} \cap H_{B4}$:	23.53 (3)**	0.000
H_{B11}:	$H_{B1} \cap H_{B5}$:	7.001 (3)	0.071
H_{B12}:	$H_{B2} \cap H_{B5}$:	13.80 (3)**	0.003

Testing for weak exogeneity restrictions.

		$\chi^2(dof)$	p-value
H_{B13}:	$H_{B1} \cap$ weak exogeneity of p_G^c wrt β_{B1}:	5.939 (2)	0.055
H_{B14}:	$H_{B1} \cap$ weak exogeneity of e_G wrt β_{B1}:	9.503 (2)**	0.008
H_{B15}:	$H_{B1} \cap$ weak exogeneity of p_{GR}^c wrt β_{B1}:	6.051 (2)*	0.049

$$\beta_{B2} : p^c_{IT} + 2.811(0.290)p^c_G - 1.728(0.165)p^c_{GR}$$

In the accepted structure, β_{B1} expresses "weak" Greek-German PPP and β_{B2} a cointegration relationship among the price indices.

Tests for weak exogeneity.

The outcome of the weak exogeneity testing assuming the long run structure as specified by H_{B11}, is given at the lower part of the Table 5.4. H_{B13}, H_{B15} and H_{B14} test for weak exogeneity of the German prices, the Greek prices and the drachma/mark exchange rate respectively, with respect to the parameters of the first cointegrating vector: H_{B13} is accepted by the data set, while H_{B15} H_{B15} are not: consistent with the results in system (A) analysis, German prices are the only exogenous variable in the Greek-German PPP relationship.

Concluding, we would say that there is evidence for "weak" PPP between Greece and Germany, while there is no evidence for "weak" PPP between neither Greece and Italy nor Germany and Italy[11], results which probably reflect the EMS performance of the countries. Weak exogeneity with respect to the Greek-German PPP is accepted just for the German prices, result which is consistent with the system (A) analysis; the estimated magnitude of the coefficients of the Greek-German weak PPP relation are, though, lower than the ones obtained in the system (A) and "strong" PPP is rejected. However, it should be remembered that in the present stage we identified a long run relationship between p_{GR}, p_G and e_G, using a shorter sample period, than in the system (A) due to lack of Italian lira/drachma exchange rate series data.

[11]The fact that there is evidence for a cointegrating relation which is very close to "weak" PPP between France and Germany, while such a relation cannot be supported between Italy and Germany is in accordance with the results obtained by Chen (1995), where he tests for PPP between EMS countries by testing for stationarity of a number of real exchange rates using producer price indices for the period 1974(4) -1990(12).

5.2.3 The Long-Run structure of the VAR system C.

The cointegration space rank.

Model (3) as specified in section 3 for a vector of the form:

$x_t = (e_{FR}, e_G, p_G^w, p_{GR}^w, p_{FR}^w)$ provides the framework to perform the multivariate cointegration analysis. The outcomes of the maximum eigenvalue and trace statistics, the estimated eigenvectors and their loadings are reported in Table 5.5. Both two likelihood ratio tests support the cointegrating space rank to be three, so we continue the analysis based on this assumption. In addition, visual examination of the graph of the three recursively calculated eigenvalues given in figure 4 provides evidence for the parameter constancy of the cointegrating relations.

Identification of the Long Run structure.

Even though some of the unconstrained eigenvectors seem to imply reasonable relations, formal testing is performed. Table 5.6 presents the outcomes of a number of likelihood ratio statistics testing for alternative theoretical assumptions concerning the specification of the three cointegrating vectors.

Assumptions on a single cointegrating vector framework are followed by assumptions concerning the joint structure of the cointegrating space. Main assumptions tested are "weak" PPP between Greece and Germany, Greece and France, Germany and France. The assumptions implied by H_{C7} are finally shown to specify the structure of the three-dimensional cointegration space.

The three cointegrating vectors are of the form:

$$\beta_{C1} : e_G - 0.871(0.032)(p_{GR}^w - p_G^w)$$

$$\beta_{C2} : e_{FR} - 0.836(0.089)e_G + 0.588(0.078)p_{FR}^w - 0.239(0.067)p_G^w$$

$$\beta_{C3} : e_{FR} - 0.651(0.027)(p_{GR}^w - p_{FR}^w)$$

β_{C1} expresses a "weak" PPP relation between Greece and Germany, while β_{C3} a "weak" PPP relation between Greece and France. Finally, β_{C2} ex-

Table 6: **Cointegration analysis of system (C).**

Testing for the Π rank.					
Eigenvalues	H_0	Max. Eigen.	95%	Trace	95%
0.736	$r = 0$	68.03**	33.5	148.8**	68.5
0.533	$r \leq 1$	38.87**	27.1	80.79**	47.2
0.404	$r \leq 2$	26.40**	21.0	41.91**	29.7
0.239	$r \leq 3$	13.98	14.1	15.30	15.4
0.029	$r \leq 4$	1.532	3.8	1.532	3.8
Standardised eigenvectors.					
e_G	e_{FR}	p^w_G	p^w_{GR}	p^w_{FR}	
1	1.201	4.585	-2.620	-0.090	
-1.321	1	-1.427	0.495	0.611	
0.322	0.012	1	-0.391	-0.148	
-0.499	-0.434	-2.485	1	-0.013	
-1.070	0.037	-3.938	1.107	1	
Adjustment coefficients.					
e_G	0.565	0.240	-2.023	0.178	0.009
e_{FR}	0.529	-0.202	-2.716	0.224	0.021
p^w_G	-0.097	0.003	-0.060	0.032	0.007
p^w_{GR}	0.153	-0.053	-0.298	-0.038	0.051
p^w_{FR}	-0.064	-0.146	0.913	0.160	0.008

presses a relation between the Deutsch mark/ French frank exchange rate and the French and German price indices, which could imply a "weak" PPP relation between the two countries. The results reinforce the findings obtained in the system (A) analysis.

Weak exogeneity tests.

Weak exogeneity tests are reported in the lower part of table 5.6. Consistent with the system (A) results, e_G turns out to be the only exogenous variable in the Greek-German PPP relation. Weak exogeneity of the varia-

Table 7: **Testing system (C) for structural and exogeneity restrictions.**

Testing restrictions on single vectors specification.

		e_{FR}	e_G	p^w_G	p^w_{GR}	p^w_{FR}	$\chi^2(dof)$	p-value
H_{C1}:	β_{C1}:	0	1	a	-a	0	4.700 (1)*	0.030
H_{C2}:	β_{C3}:	1	0	0	-b	b	5.205 (1)*	0.022
H_{C3}:	β_{C2}:	1			0		n a c	
H_{C4}:	β_{C2}:	1	-1	-c	0	c	5.192 (1)*	0.022

Testing for joint restrictions.

		$\chi^2(dof)$	p-value
H_{C5}:	$H_{C1} \cap H_{C4}$:	12.211 (2)**	0.002
H_{C6}:	$H_{C2} \cap H_{C4}$:	11.452 (2)**	0.003
H_{C7}:	$H_{C1} \cap H_{C2} \cap H_{C3}$:	5.208 (2)	0.074
H_{C8}:	$H_{C1} \cap H_{C2} \cap H_{C4}$:	37.353 (3)**	0.000

Testing for weak exogeneity restrictions.

		$\chi^2(dof)$	p-value
H_{C9}:	$H_{C7}\cap$ w. exogeneity of p^w_{GR} wrt β_{C1}:	10.382 (4)*	0.034
H_{C11}:	$H_{C7}\cap$ w. exogeneity of p^w_G wrt β_{C1}:	9.485 (4)	0.050
H_{C12}:	$H_{C7}\cap$ w. exogeneity of e_G wrt β_{C1}:	14.50 (4)**	0.005
H_{C13}:	$H_{C7}\cap$ w. exogeneity of p^w_{GR} wrt β_{C3}:	14.68 (4)**	0.005
H_{C14}:	$H_{C7}\cap$ w. exogeneity of p^w_{FR} wrt β_{C3}:	9.467 (4)	0.052
H_{C15}:	$H_{C7}\cap$ w. exogeneity of e_{FR} wrt β_{C3}:	32.19 (4)**	0.000

Testing for reduction to bi-lateral systems.

H_{C16}:	$H_{C7}\cap$ w. ex. of p^w_{FR}, e_{FR} wrt β_{C1}:	24.45 (8)**	0.001
H_{C17}:	$H_{C7}\cap$ w. ex. of p^w_G, e_G wrt β_{C3}:	16.11 (8)*	0.043

bles with respect to the vector expressing the "weak" French-Greek PPP relationship is accepted just for the case of p^c_{FR}. Contrary to the system (A) results, weak exogeneity of e_{FR} is also rejected.

Testing for reduction to bi-lateral systems.

Finally, testing for reduction to bi-lateral systems demonstrates that, even though this is feasible for the Greek-German system (in the margin though), this is not so for the Greek-French relationship.

5.2.4 The Long-Run structure of the VAR system D.

The cointegration space rank.

Cointegration analysis is performed on a wellspecified VAR for the vector of the form: $x_t = (e_G, e_{FR}, p^w_{GR}, p^w_G, p^w_{FR})$. The outcomes of the maximum eigenvalue and trace statistics, the estimated eigenvectors and their loadings are given in Table 5.7. There is evidence of two cointegrating relationship as supported by the trace likelihood ratio statistic, which are also relatively constant as indicated by the recursively calculated eigenvalues shown in figure 5.

Identification of the Long Run structure.

Hypothesis testing results concerning the structure of the two cointegrating vector are reported in the upper part of table 5.8. H_{D8} assumes jointly a "weak" PPP relation between Greece and Germany for β_{D1} and a non-specified cointegrating relationship between e_G, e^w_{IT}, p^w_G and p^w_{IT} for β_{D2}. It is accepted with the highest *p-value* by the given data set and, therefore, the analysis is continued based on this specification.

Weak exogeneity tests.

Weak exogeneity tests are reported in the lower part of table 5.9: H_{D9}, H_{D10}, H_{D11}, test for weak exogeneity of e_G, p^w_{GR}, p^w_G respectively, with

Table 8: **Cointegration analysis of system (D).**

Testing for the Π rank.					
Eigenvalues	H_0	Max. Eigen.	95%	Trace	95%
0.5491	r = 0	48.59**	33.5	112.5**	68.5
0.4801	r ≤ 1	39.90**	27.1	63.87**	47.2
0.2496	r ≤ 2	17.52	21.0	23.96	29.7
0.0957	r ≤ 3	6.143	14.1	6.443	15.4
0.0049	r ≤ 4	0.300	3.8	0.300	3.8
Standardised eigenvectors.					
e_G	e_{IT}	p^w_G	p^w_{GR}	p^w_{IT}	
1	-0.236	3.981	-0.644	-1.379	
8.400	1	42.37	-8.049	-11.28	
-0.223	0.169	1	0.226	-0.561	
-0.108	-0.864	-1.933	1	-0.251	
-0.222	0.194	-1.406	-0.219	1	
Adjustment coefficients.					
e_G	-0.022	0.015	0.581	0.021	0.034
e_{IT}	-0.019	0.029	0.054	0.065	0.081
p^w_G	-0.005	-0.013	-0.040	0.006	0.008
p^w_{GR}	0.117	-0.002	-0.038	-0.136	0.038
p^w_{IT}	0.246	-0.019	-0.026	0.012	0.014

respect to the parameters of the "weak" Greek-German PPP. Consistent with the analysis of the previous systems, weak exogeneity is not rejected just for the case of p^w_G.

5.3 Interpretation of the results.

The results obtained in the first stage of testing for PPP in a multilateral framework are indicative of the way Greek exchange rates and prices were determined during the period examined. First of all, there is evidence for cointegrating relationships of the form $\gamma_1 e - \gamma_2 p + \gamma_3 p_f$ related with the

Table 9: **Testing system (D) for structural and exogeneity restrictions.**

Testing for structural restrictions.

		e_G	e_{IT}	p^w_{GR}	p^w_G	p_{IT}	$\chi^2(dof)$	p-value
H_{D1}:	β_{D1}:	1	0	-a	a	0	3.422 (2)	0.180
H_{D2}:	β_{D1}:	0	1	-b	0	b	12.09 (2)**	0.002
H_{D3}:	β_{D2}:	0	0	1	-c	-d	2.546 (1)	0.110
H_{D4}:	β_{D2}:	1	-1	0	a	b	0.012 (1)	0.912
H_{D5}:	β_{D2}:	1	a	0	b	c	n a c	
H_{D6}:	β_{D1}:	1	0	-1	1	0	29.69 (3)**	0.000

Testing for joint restrictions.

		$\chi^2(dof)$	p-value
H_{D7}:	$H_{D1} \cap H_{D3}$:	6.616 (3)	0.085
H_{D8}:	$H_{D1} \cap H_{D5}$:	2.972 (3)	0.396

Testing for weak exogeneity restrictions.

		$\chi^2(dof)$	p-value
H_{D9}:	$H_{D1} \cap$ w. exogeneity of e_G wrt β_{D1}:	7.396 (2)*	0.024
H_{D10}:	$H_{D1} \cap$ w. exogeneity of p^w_{GR} wrt β_{D1}:	7.716 (2)*	0.021
H_{D11}:	$H_{D1} \cap$ w. exogeneity of p^w_G wrt β_{D1}:	2.957 (2)	0.227

long run behaviour of all three exchange rates e_G, e_{FR} and e_{IT} in most of the systems. This is consistent with these European countries being the three main trading partners of Greece with special trading agreements, especially after Greece became an EEC member in January 1981. Moreover, from March 1979, the EMS mechanism existed, according to which the participating countries had to maintain the market exchange rates of their currencies against the ECU (essentially the Deutsch mark) within particular bands, for mainly antiinflationary reasons[12].

However, joint testing of the hypotheses revealed that:

a) The strongest relationship is the one implying "weak" PPP between Greece and Germany. Such a relationship is supported by all three-country systems using the two alternative price indices[13]. The result is easily interpreted given that Germany has been the largest trading partner of Greece for the period under consideration, with the Deutsch Mark being the most powerful European currency. In the relationship, Greek prices and the e_G are the endogenous variables with respect to the long run parameters. The status of the variables indicates that, during the period, the exchange rate moved in a way to keep Greece's competitiveness against Germany relatively constant, while influencing Greek price formation. The strength of the relationship is also verified by the fact that it can be identified in reduced two-country systems as shown by relevant weak exogeneity tests. Finally, as indicated by the recursively estimated eigenvalues, the relationship has constant parameters.

b) A constant parameter "weak" PPP is also accepted between Greece and France in the two relevant systems, in which, though, there is also evidence for a cointegrating long run relationship very close to "weak" PPP between Germany and France. In addition, in both systems (systems (A) and (C)), the French variables are not weakly exogenous with respect to the parameters of the estimated weak Greek-German PPP; in other words,

[12]Greece did not participate in the EMS, even though the drachma was added to the ECU basket in September 1984.

[13]The weak PPP hypothesis is accepted obtaining different coefficient values in different systems, and in system (A) even "strong" PPP is accepted, but this can be due to the different data samples.

the Greek-French PPP is identified only when analysis of the joint distribution of the variables is performed. The results indicate that the "weak" PPP between Greece and France is a "secondary" relation caused by the fact that both countries tried to keep relatively constant competitiveness against Germany, and that the franc was strongly linked to the Deutsch mark.

c) There is no evidence for "weak" PPP between Greece and Italy, a result which at first seems strange, given that Italy is more important a trading partner of Greece than France. The result, however, reinforces the interpretation given above for the French case. This interpretation seems reasonable if, in addition, we take into account that there is no evidence for weak PPP between Germany and Italy[14], and the fact that the French franc was for the whole EMS period participating in the ERM mechanism within lower bands (2.25% on each side of the central parity against ECU) than the Italian currency (6% on each side of the central parity).

The multilateral analysis gave evidence for two weak PPP relationships, revealing at the same time relationships between the variables of the system which were out of the initial scope of the analysis. In addition, it indicated that there is no scope for testing for PPP in a bilateral framework in any but the Greek-German case. It was decided, however, to continue the analysis in bi-lateral systems for the sake of curiosity.

6 Testing for PPP in a bilateral framework.

6.1 Specification of the VAR models.

In a second stage, PPP is tested between Greece and each of its three major trading partners, in a two country system framework. To this end, six three-dimensional VAR systems for the three exchange rates using the two alternative price indices which analyse vector processes of the form $z_t = (e, p, p_f)$ are formulated. The estimated VARs allow for a set of

[14] Finding consistent with the work by Chen (1995).

conditioning variables, D_t: a constant and seasonal dummies for all VARs and different impulse dummy variables, to account for different regime shifts that characterise the performance of the different economies. Once the VARs are shown to be congruent, the Johansen technique estimates the number of the stationary linear combinations of the variables of the form:

$$\gamma_1 e + \gamma_2 p + \gamma_3 p_f \tag{11}$$

In the case that there is evidence of one stationary relationship (one cointegrating vector) among the variables, the theoretical restrictions of interest can be assessed. The first theoretical assumption H_1 to be tested for, is that expressed by the "weak" PPP version allowing for transportation costs/ measurement errors as formalised in (2). This implies jointly the restrictions:

$$H_1 : \gamma_1 = 1, -\gamma_2 = \gamma_3 (= \gamma) \tag{12}$$

Finally, and in the case that the assumption H_1 has not been rejected, the "strong" PPP version (1) can be assessed by testing for H_2 which implies jointly the restrictions:

$$H_2 : \gamma_1 = 1, \gamma_2 = -1, \gamma_3 = 1. \tag{13}$$

All six VARs were initially estimated by applying multivariate least squares using five lags of the variables (k=5). First of all, none of the initial 5th order systems presented autocorrelated residuals. However, the final number of lags of the endogenous variables used for each estimated VAR was specified by sequential testing of the initial systems against specifications of lag length k-1 by means of the likelihood test, until the shorter lag length k-1 was rejected against some value of k, provided there were non autocorrelated residuals in the estimated reductions. Therefore, the number of lags used finally for each VAR system was: five lags for the France using p^c's VAR and the Germany using p^w's VAR; three lags for

Table 10: **Bilateral systems' eigenvalues.**

VARs using p^w's.			
$z_t = (e, p_f^w, p_{GR}^w)$			
Germany	0.261	0.122	0.016
Italy	0.481	0.167	0.009
France	0.486	0.138	0.006

VARs using p^c's			
$z_t = (e, p_f^c, p_{GR}^c)$			
Germany	0.230	0.068	0.000
Italy	0.296	0.049	0.016
France	0.257	0.163	0.012

the German VAR using p^c's; four lags for the rest of the systems. Normality problems indicated a number of dummies to be included in D_t to account for specific regime shifts that characterise the examined period shown (also) by Chow tests for parameter constancy. The events that the dummies account for are described in Appendix 1.

Tables 3 and 4 in Appendix 2 summarise the properties of the final systems' residuals obtained by the VARs using p^w's, and the VARs using p^c's, respectively. The number of lags of the variables used and the variables contained in the D_t set for each system are mentioned in the first lines of the tables. Single equation diagnostics are first reported, followed by the diagnostics for the VARs residuals. They do not indicate serious autocorrelation, and non-normality problems for any of the cases.

6.2 The long run structure. Testing for PPP as a cointegrating relationship.

The cointegration rank.

Table 11: **Two-country VARs Cointegration Analysis.**

	Maxim.	eigenv.		Trace		
	$r = 0$	$r \leq 1$	$r \leq 2$	$r = 0$	$r \leq 1$	$r \leq 2$
95%	21.0	14.1	3.8	29.7	15.4	3.8
VARs using p^w's						
Germany	21.49*	9.25	1.20	31.95*	10.46	1.20
Italy	31.49**	8.82	0.04	40.36**	8.870	0.04
France	34.02**	7.57	0.31	41.91**	7.880	0.31
VARs using p^c's						
Germany	21.14*	5.25	0.02	26.82	5.280	0.02
Italy	21.83*	3.11	1.00	25.95	4.110	1.00
France	21.11*	12.7	0.91	34.71*	13.61	0.91

Model (3) for a vector of the form $z_t = (e, p, p_f)$ is the starting point of the cointegration analysis. Given that the exchange rate and price series have a linear trend, evidence consistent with the assumption of constant nominal price growth, the analysis is again continued without imposing the constant to lie in the cointegrating space in all VARs. Table 6.1 presents the obtained eigenvalues while table 6.2 reports the outcomes of the two likelihood ratio tests testing for the cointegration rank r of the matrix Π for the six systems.

There is evidence of one cointegrating relationship for all systems. Table 6.4 reports the unrestricted form of the eigenvectors accepted to express stationary relationships, normalized with the value corresponding to the nominal exchange rate and the adjustment coefficients for each accepted eigenvector. The eigenvectors of all but the French system using p^w's emerge as having coefficients with the theoretically expected sign and magnitudes which could support a PPP relation.

Table 12: **Two-country VARs cointegrating vectors and adjustment coefficients.**

	Coint.	Vector			Adjust.	Coeff.	
VARs using p^w's.							
	e	p_f^w	p_{GR}^w	const	e	p_f^w	p_{GR}^w
Germany	1	1.830	-1.091		-0.07	0.22	-0.84
Italy	1	1.880	-1.560		0.02	0.05	-0.00
France	1	-0.602	-0.671		-0.16	0.00	0.00
VARs using p^c's							
	e	p_f^c	p_{GR}^c		e	p_f^c	p_{GR}^c
Germany	1	2.098	-1.136		-0.12	-0.02	0.02
Italy	1	3.362	-1.143		-0.00	0.06	0.01
France	1	0.737	-0.840		-0.20	0.02	0.01

Table 13: **Tests for structural restrictions on the cointegrating vectors of the two-country systems.**

Hypothesis Test Statistic	H_1 [1] $\chi^2(1)$	Restricted coint. vector	H_2 [2] $\chi^2(2)$
VARs using p^w's			
		(e, p^w_f, p^w_{GR})	
Germany	2.76	(1, 0.857, -0.857)	10.945**
Italy	23.42**		
France	19.15**		
VARs using p^c's			
		(e, p^c_f, p^c_{GR})	
Germany	5.97*	(1, 0.924, -0.924)	15.79**
Italy	8.71**		
France	0.73	(1, 0.867, -0.867)	6.142*

[1] H_1 tests for "weak" PPP

[2] H_2 tests for "strong" PPP

Testing for PPP as a structural restriction.

The next step is to test for the restrictions implied by the "weak" PPP version as expressed by the hypothesis H_1, by applying the likelihood ratio test given by (10). The results are reported in the first column of table 6.4. The restrictions that H_1 implies are accepted for the following VAR systems:

Both VARs modelling the determination of the Deutsch mark/ drachma exchange rate e_G using p^w's and p^c's; the restriction is, though, just marginally accepted with a p: 0.0145 (rejected at a 5% but not at a 1% level of significance) for the system using p^c's. The accepted relationships are of the form (with standard errors given in parentheses):

$$e_G = 0.857(0.037)(p^w_{GR} - p^w_G)$$

$$e_G = 0.924(0.021)(p^c_{GR} - p^c_G)$$

The system modelling the French franc exchange rate using p^c's, with accepted weak PPP relationship of the form:

$$e_{FR} = 0.867(0.039)(p^c_{GR} - p^c_{FR})$$

For all accepted cointegrating relationships the magnitude of γ is close to unity, which evidence implies that they possibly express PPP relationships. For the rest of the VAR systems the weak PPP restriction of equal coefficients and opposite signs for the price variables was strongly rejected.

The next step is to test for the restrictions of the strong PPP implied by hypothesis H_2, in the cases where the proportionality assumption is not rejected. The results are given in the third column of table 6.4. The restrictions were rejected for all cases.

Finally, the robustness of the three obtained weak PPP relations is assessed by visual examination of the graphs of the recursive estimates of the eigenvalues of the three systems. They are presented in figure 6. They are constant for all but the French system thus casting doubt on the validity of its results. The Greek-German using both indices PPP relations are, therefore, the two most robust relations that come out of the bi-lateral analysis.

Weak exogeneity tests.

The weak exogeneity status of the variables with respect to the long run parameters of interest is tested for the cases where the weak PPP hypothesis is not rejected by the given data sets. The results are reported in table 6.5.

In the Greek-German system using p^c's, weak exogeneity for the exchange rate variable is rejected, while weak exogeneity for Greek prices is accepted (even though marginally), in contrast to the multilateral systems (A) and (B). Rejection of the weak exogeneity for the e_{FR} with respect to the Greek-French PPP is also in contrast with the result obtained in

Table 14: **Testing for weak exogeneity restrictions.**

Hypothesis	$\chi^2(dof)$	p-value
a. Testing the Greek - German p^w system		
H_{a1}: w. exogeneity for p^w_G:	6.365 (3)	0.095
H_{a2}: w. exogeneity for p^w_{GR}:	9.908* (3)	0.019
H_{a3}: w. exogeneity for e_G:	9.186* (3)	0.026
b. Testing the Greek - German p^c system		
H_{b1}: w. exogeneity for p^c_G:	7.508 (3)	0.057
H_{b2}: w. exogeneity for p^c_{GR}:	7.437 (3)	0.059
H_{b3}: w. exogeneity for e_G:	15.054** (3)	0.001
c. Testing the Greek - French p^c system		
H_{c1}: w. exogeneity for p^c_{FR}:	4.452 (3)	0.216
H_{c2}: w. exogeneity for p^c_{GR}:	7.884 (3)*	0.048
H_{c3}: w. exogeneity for e_{FR}:	17.522 (3)**	0.000

(A); however, the result of the particular bi-lateral system is not of great importance given that the cointegrating vector does not seem to have constant parameters. Finally, in the Greek-German system using p^w's the assumptions for weak exogeneity for the Greek prices and the exchange rate are rejected, which result is consistent with both multilateral systems (C) and (D).

6.3 Interpretation of the results.

The findings obtained at this second stage verified the implications made based on the results obtained in the multi-lateral analysis: The "weak" PPP doctrine is accepted for both VARs modelling Greek-German trade interrelations. "Weak" Greek-French PPP is accepted in the system using p^c's. However, given that the p^c's cointegrating relationship does not have constant parameters as indicated by the recursive eigenvalues graph and that "weak" PPP is not accepted in the p^w's system, the result is quite inconclusive. "Weak" PPP is not accepted for the drachma/ Italian systems using both price indices. Finally, the "strong" PPP version is rejected for all cases tested. Summarising, even though there is evidence for a cointegrating relation between prices and exchange rates between Greece and its three main trading partners, the robust "weak" PPP relationships have been identified in the Greek-German systems using both price indices.

The bi-lateral analysis findings confirm mainly the ones obtained in the multi-lateral one, leaving though a number of questions (Greek-French PPP, exogeneity status of variables in the two Greek-German PPP relations) unanswered . In addition, no possible explanations for the behaviour of the series are implied.

7 Conclusions

In the present paper, the PPP hypothesis between Greece and its three major trading partners was tested using the Johansen multivariate cointegration technique, which tests for cointegration allowing for a distinction between the long run relations and short run dynamics and for adjustment for structural breaks. A basic aim of the work was also to investigate the implications that problems related with the empirical PPP literature have for the analysis. Therefore, the PPP hypothesis was tested in a multi-lateral and a bi-lateral framework, using two alternative price indices and without imposing *a priori* any endogenous/exogenous status for the variables.

The basic theoretical results are:

There is evidence for long-run weak PPP between Greece and Germany and between Greece and France. PPP with Germany is supported by all systems (multi-lateral as well as bi-lateral), using the two alternative indices and can, therefore, be considered as a robust relationship. However, PPP with France can be seen as a "secondary" relationship supported mainly by the multi-lateral systems in which PPP between Germany and France is also indicated. The results imply that Greece tried to preserve constant competitiveness mainly with Germany which is its most important trade partner with a currency that dominated the European countries (which also account for almost the two thirds of the Greek trade). On the other hand, the Greek-French PPP can be seen as a result of the fact that France tried also to preserve constant competitiveness with Germany, and that the French franc was strongly linked to the Deutsch mark through the ERM mechanism for most of the period.

With respect to the empirical PPP studies problems:

i) The multilateral analysis gave evidence for two weak PPP relationships with constant parameters. At the same time, it revealed relationships between the variables of the system which were beyond the initial scope of the analysis, which helped interpretation of the main results. In addition, it indicated that there is no scope for testing for PPP in a bilateral framework in any but the Greek-German case. Bi-lateral analysis mainly confirmed the multi-lateral findings, but provided also contradictory results. Therefore, analysis based only in bi-lateral systems, would have been rather inconclusive.

ii) Both price indices gave similar results with respect to the identification of the main long-run relationships (especially in (and probably due to) the multilateral analysis); there were minor differences between the p^c's and the p^w's systems with respect to the determination of the exogeneity status of the variables, probably indicating differences in measurement, or the industry structure of the different economics.

iii) Finally, the exogeneity status of the exchange rates and the Greek prices was rejected in most cases for which PPP was identified. Both results make sense for the case of the Greek small open economy.

APPENDIX 1: Definition of the regime shift dummy variables.

Dummies to account for breaks related to the performance of the Greek economy:

- D831: 1 in 1983:1; 0 otherwise: In January 1983 the Greek drachma is devalued by 15,5%.
- D843: 1 in 1984:3; 0 otherwise: In September 1984, drachma is added to the European Currency Unit.
- D854: 1 in 1985:4; 0 otherwise: In October 1985 measures for a stabilization package include a drachma devaluation by 15%.

Dummies that enter the French VARs:

- D771: 1 in 1977:1; 0 otherwise: A liberalisation of the goods prices (which were frozen in the previous months) and VAT change take place in January 1977.
- D801: 1 in 1980:1; 0 otherwise: In France, energy prices and oil products prices rise sharply in January 1980, as a result of the second oil price shock, which took place at the begining of 1979.
- D822: 1 in 1982:2; 0 otherwise: In June 1982, a realignment of the French franc in the EMS takes place (The French franc depreciates by 6%).
- D852: 1 in 1985:2; 0 otherwise: At the beginning of 1985 a number of price control measures were lifted, with the fuel and automobile price controls lifted in February and July 1985 respectively.

Dummies that enter the German VARs:

- D791: 1 in 1979:1; 0 otherwise: To account for the sharp rise in the prices of oil products.
- D803: 1 in 1980:3; 0 otherwise: To account for a temporary fall in prices caused by tight monetary policy measures.

- D814: 1 in 1981:4; 0 otherwise: A realignment of 5.5 % of the Deutsch mark in the EMS takes place in October 1981.

Dummies that enter the Italian VARs:

- D801: 1 in 1980:1; 0 otherwise: Public services and energy prices rise in January 1980 in order to accomodate the second oil price shock.
- D911: 1 in 1991:1; 0 otherwise: In January 1991, public spending cuts as decided in the state budget and a wage freezing accord had as a result a fall in inflation.
- D924: 1 in 1992:4; 0 otherwise: Withdrawal of the Italian lira from the ERM in September 1992.

APPENDIX 2: Diagnostics of the VAR systems.

Table 1: **Diagnostics of the multi-country VARs using p^c's.**

	A) Greek- German-French VAR	B) Greek- German-Italian VAR
Sample:	1976.2-1993.4	1978.4-1993.4
Dummies in D_t:	D854, D822, D852, D831, D832, D843.	D854, D801, D911, D831, D832, D924.
Lags used:	5	5

Equations residuals tests

AR F(.,.) (cr. value ≈	F(5,31) 2.52)	F(4, 23) 2.80
	e_G: 1.190	e_G: 1.198
	e_{FR}: 1.060	e_{IT}: 2.783
	p^c_{GR}: 0.987	p^c_{GR}: 1.034
	p^c_G: 1.989	p^c_G: 3.90*
	p^c_{FR}: 1.255	p^c_{IT}: 2.062

N χ^2 (2) (cr.value: 5.99)

	e_G: 3.11	e_G: 4.272
	e_{FR}: 5.177	e_{IT}: 2.953
	p^c_{GR}: 2.454	p^c_{GR}: 1.634
	p^c_G: 2.670	p^c_G: 1.461
	p^c_{FR}: 0.481	p^c_{IT}: 3.512

VARs residuals tests

Vec AR F(.,.) (cr. value ≈	F(125, 39) 1.58	F(100, 19) 1.70)
	0.998	1.389

VecN $\chi^2(10)$ (cr. value: 18.31)

	15.096	16.028

Table 2: **Diagnostics of the multi-country VARs using p^w's.**

	C) Greek- German-French VAR	D) Greek- German-Italian VAR
Sample:	1981.2-1993.4	1978.4-1993.4
Dummies in D_t:	D854, D861, D831, D822.	D854, D911, D924, D831, D832.
Lags used:	5	4
Equations residuals tests		
AR F(.,.)	F(3, 15)	F(4, 28)
(cr. value ≈	3.29	2.78
	e_G: 3.807*	e_G: 2.050
	e_{FR}: 2.013	e_{IT}: 1.225
	p^w_{GR}: 3.256	p^w_{GR}: 2.696
	p^w_G: 1.670	p^w_G: 2.782
	p^w_{FR}: 3.197	p^w_{IT}: 2.677
N χ^2 (2) (cr.value: 5.99)		
	e_G: 0.387	e_G: 1.802
	e_{FR}: 2.425	e_{IT}: 3.311
	p^w_{GR}: 1.758	p^w_{GR}: 2.383
	p^w_G: 8.516*	p^w_G: 1.319
	p^w_{FR}: 0.200	p^w_{IT}: 4.569
VARs residuals tests		
Vec AR F(.,.)	F(.,.)	F(100, 43)
(cr. value ≈		1.60)
	$n\ a$	1.499
VecN $\chi^2(10)$ (cr. value: 18.31)		
	18.087	8.701

Table 3: **Diagnostics of the two-country VARs using p^w's.**

	Germany	Italy	France
Sample:	1976.2-1993.4	1978.1-1990.1	1981.2-1993.4
Dummies included in D_t:	D854, D831, D791, D814.	D854, D831.	D854, D861, D831, D832, D822.
Lags used:	5	4	4
Equation residual tests			
AR F(.,.)	F(5, 43)	F(4, 29)	F(4, 26)
(cr. value ≈	2.43	2.70	2.74
e	2.30	1.558	2.927*
p^w_{GR}	1.23	0.408	0.047
p^w_f	0.69	0.346	1.296
N χ^2 (2) (cr.value: 5.99)			
e	0.04	2.907	4.337
p^w_{GR}	3.12	0.219	0.228
p^w_f	0.01	0.019	1.898
VAR residual tests			
Vec AR F(.,.)	F(45, 92)	F(36, 56)	F(36, 48)
(cr. value ≈	1.50	1.65	1.62
	1.02	1.0752	1.547
VecN $\chi^2(6)$ (cr. value: 12.59)			
	2.58	10.932	7.558

Table 4: **Diagnostics of the two-country VARs using p^c's.**

	Germany	Italy	France
Sample:	1975.3-1993.4	1978.3-1993.4	1976.1-1993.1
Dummies included in D_t:	D854, D861, D791, D831, D832, D801, D924, D931.	D854, D831, D801, D924.	D854, D831, D823, D832, D801.
Lags used:	3	4	5
Equation residual tests			
AR F(.,.)	F(5, 48)	F(4, 37)	F(5, 42)
(cr. value ≈	2.43	2.62	2.42
e	1.185	0.755	1.243
p^c_{GR}	3.217*	0.459	0.516
p^c_f	1.113	1.383	0.580
N χ^2 (2) (cr.value: 5.99)			
e	5.686	3.899	4.991
p^c_{GR}	1.948	4.701	4.558
p^c_f	2.443	1.490	2.889
VAR residual tests			
Vec AR F(.,.)	F(45,107)	F(36, 80)	F(45, 89)
(cr. value ≈	1.51	1.60	1.54
	1.071	0.997	1.042
VecN χ^2(6) (cr. value: 12.59)			
	9.146	10.139	10.479

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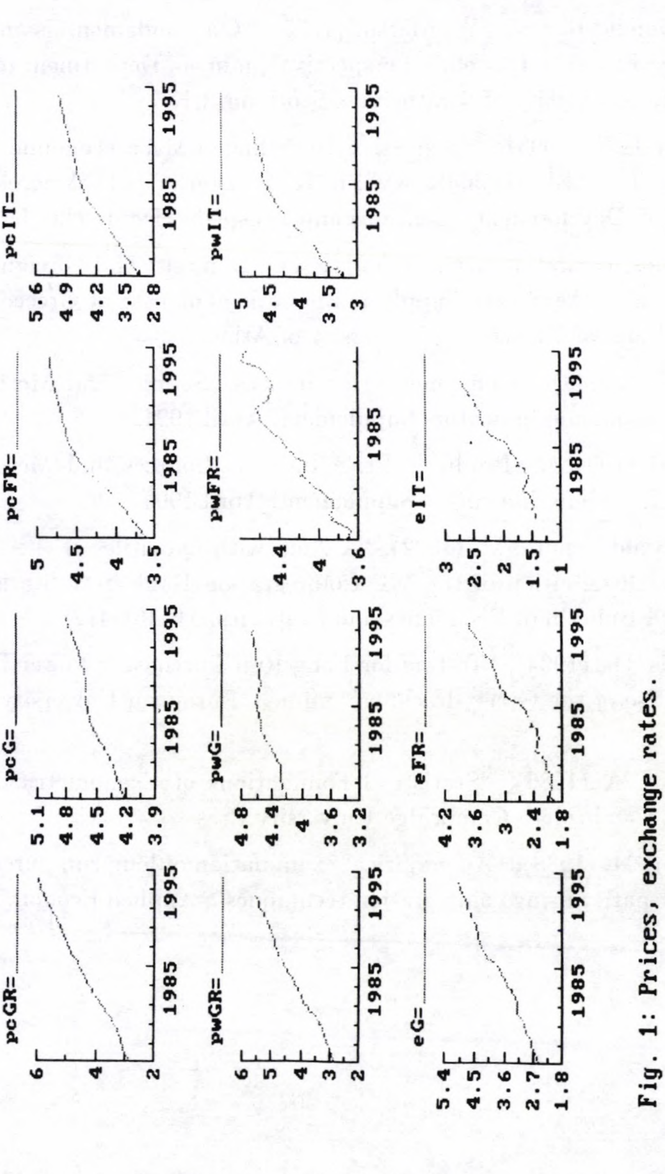

Figure 1: The series

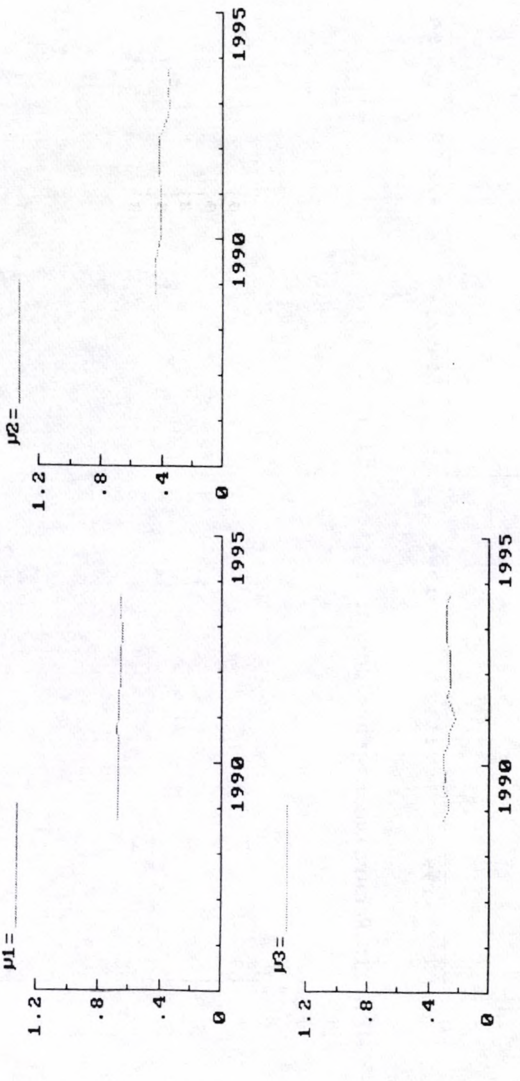

Fig.2: Recursive eigenvalues of system (A).

Figure 2: Recursive eigenvalues of system A.

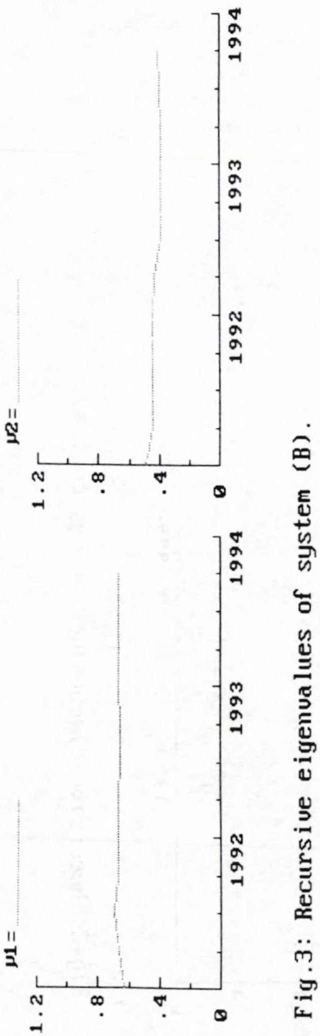

Figure 3: Recursive eigenvalues of system B.

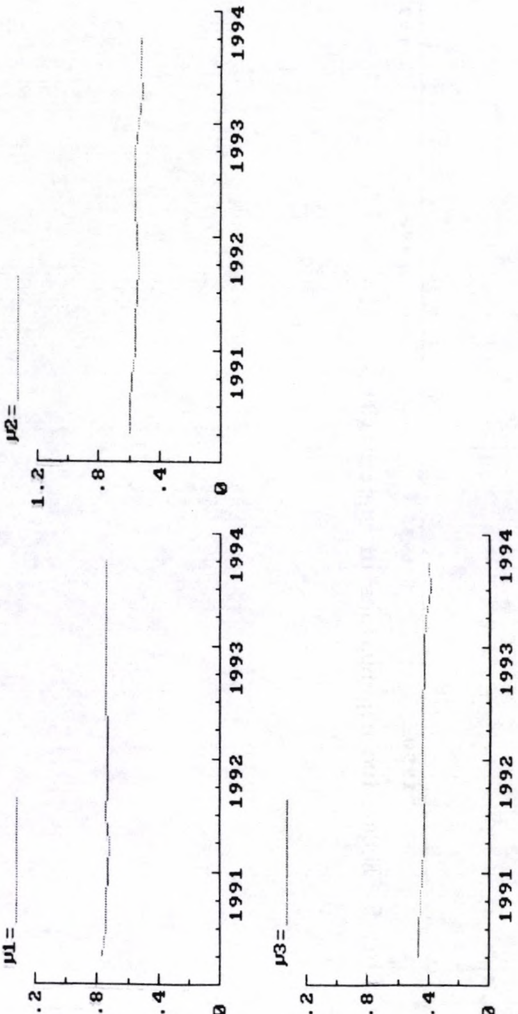

Fig. 4: Recursive eigenvalues of system (C).

Figure 4: Recursive eigenvalues of system C.

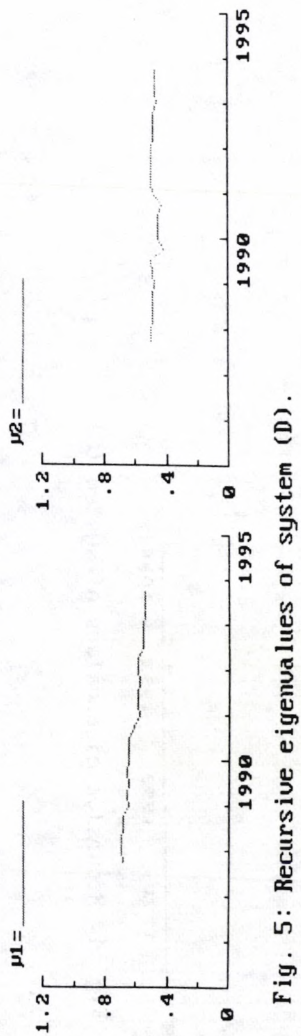

Figure 5: Recursive eigenvalues of system D.

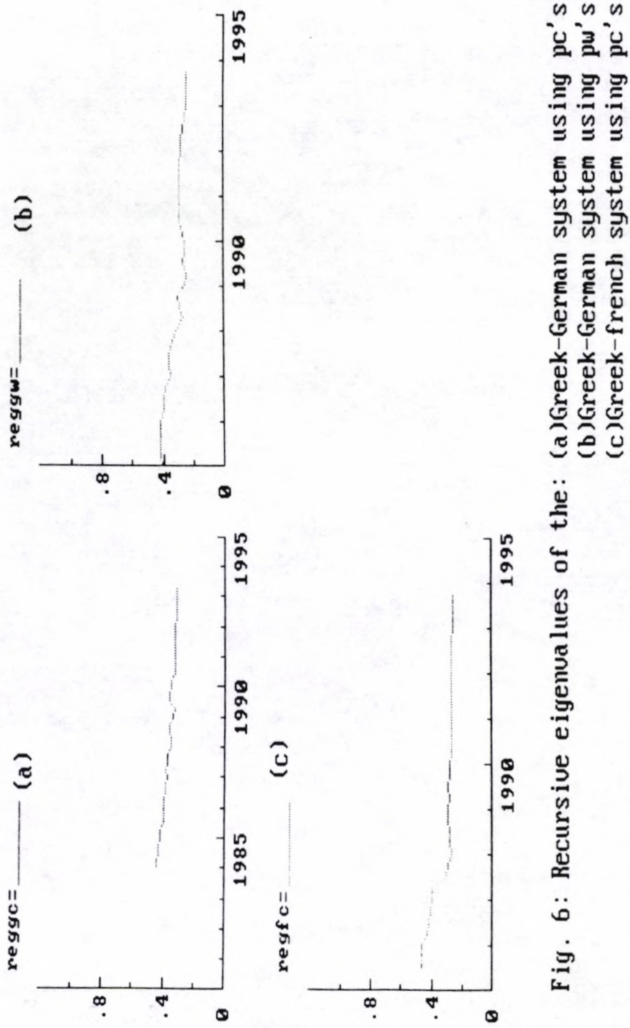

Figure 6: Recursive eigenvalues of bilateral systems.

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